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THE MSG-2 COMMERCIAL AIRLINE CONCEPT:
A DEPARTMENT OF DEFENSE PROGRAM FOR
RELIABILITY-CENTERED MAINTENANCE

STUDY PROJECT REPORT
PMC 77-2

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SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (*and Subtitle*) THE MSG-2 COMMERICAL AIRLINE CONCEPT: A DEPARTMENT OF DEFENSE PROGRAM FOR RELIABILITY-CENTERED MAINTENANCE		5. TYPE OF REPORT & PERIOD COVERED Study Project Report 77-2 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*s*) FRANCIS W. A'HEARN		8. CONTRACT OR GRANT NUMBER(*s*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS DEFENSE SYSTEMS MANAGEMENT COLLEGE FT. BELVOIR, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DEFENSE SYSTEMS MANAGEMENT COLLEGE FT. BELVOIR, VA 22060		12. REPORT DATE 77-2 13. NUMBER OF PAGES 59
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)		15. SECURITY CLASS. (*of this report*) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

UNLIMITED

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

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DEFENSE SYSTEMS MANAGEMENT COLLEGE

STUDY TITLE: THE MSG-2 COMMERCIAL AIRLINE CONCEPT: A DEPARTMENT OF DEFENSE PROGRAM FOR RELIABILITY-CENTERED MAINTENANCE

STUDY PROJECT GOALS:

To explore the development of reliability-centered maintenance in the commercial sector leading to its adoption by the Department of Defense; to examine the approaches used by the Army, Navy, and Air Force in implementing the concept and to assess the current status of their programs.

STUDY REPORT ABSTRACT:

MSG-2 is a planning and analysis technique developed by the commercial airlines to streamline scheduled maintenance requirements by capitalizing upon the inherent reliability of systems and equipment through greater use of condition monitoring.

The study examines MSG-2 development in the commercial sector along with the substantial successes realized in reducing support costs that prompted the Department of Defense to incorporate MSG-2 into its own Reliability-Centered Maintenance (RCM) program.

Army, Navy, and Air Force approaches for implementing RCM are analyzed in detail. The current status and future plans for aircraft/equipment programs subjected to the analysis are also examined.

Features of the three Services' approaches are contrasted and a number of conclusions are drawn concerning RCM training, contract versus organic efforts, and new procurement versus existing inventory aircraft systems. Finally, several recommendations for further research and policy changes are suggested.

SUBJECT DESCRIPTORS:

Systems Engineering Management, Reliability Availability, Maintainability (10.05.02); Reliability-Centered Maintenance; Aircraft Scheduled Maintenance Planning

NAME, RANK, SERVICE	CLASS	DATE
Francis W. A'Hearn, Major, USAF	PMC 77-2	November 1977

THE MSG-2 COMMERCIAL AIRLINE CONCEPT: A DEPARTMENT OF DEFENSE PROGRAM FOR RELIABILITY-CENTERED MAINTENANCE

Individual Study Program

Study Project Report

Prepared as a Formal Report

Defense Systems Management College

Program Management Course

Class 77-2

by

Francis William A'Hearn
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November 1977

Study Project Advisor
Lt Col Joseph Arcieri, USAF

EXECUTIVE SUMMARY

In the past decade the Department of Defense has experienced a rather dramatic rise in aircraft operating and support costs to the point where those expenses now account, conservatively, for more than 50% of a system's life cycle costs. In the same period, commercial aviation has succeeded in reducing its maintenance costs by something approximating 30%. Part of the explanation for this disparity centers on a concept known as MSG-2.

MSG-2 is a decision logic tree approach developed by the commercial airlines with the introduction of wide-bodied jet aircraft. The concept is designed to streamline scheduled maintenance requirements by capitalizing, to the maximum extent possible, upon system and equipment inherent reliability through the increased use of on condition maintenance and condition monitoring.

Prompted by success in the commercial sector and early Navy studies in this area, the Office of the Secretary of Defense directed the Services to incorporate the MSG-2 (or reliability-centered maintenance (RCM) approach) in their aircraft scheduled maintenance programs.

Following favorable results on a pilot MSG-2 effort with its P-3 aircraft, the Navy has developed a rather extensive program and in-house expertise for applying RCM to its aircraft systems. An RCM training program has also been developed.

The Air Force has a similarly comprehensive program that began with heavy reliance upon contractual effort but is now gradually turning to greater organic capability. Virtually all Air Force aircraft systems are being subjected to MSG-2 analysis. Resulting decreased maintenance

requirements for one system have already prompted a manpower authorization cut in excess of 800 spaces.

The Army program was most recent among the Services to formally incorporate MSG-2 logic, although it appears that much of the real substance of the concept had already been evolving in the Army's Integrated Logistic Support program for several years. Aircraft scheduled maintenance programs are being improved through MSG-2 application to the extent that the Army may be able to divest itself of some aviation depot capacity.

ACKNOWLEDGEMENTS

A single author's name on the cover of this document should not obscure the fact that the total research effort has really been the combined endeavor of many people to whom I owe sincere gratitude. A special thanks is due my wife, Sharon, and my sons, Noel and Scott, for their enduring patience and understanding during the hours and months this effort kept me too often away from them.

Invaluable assistance was provided by a number of prominent individuals who were gracious enough to share their time with me in some most rewarding personal interviews. Particular thanks in that regard are due: Mr. Charles Smith, OASD (MRA&L); Mr. Joseph Saia, NAVAIR; Mr. John Kelley, HQ USAF; Colonel E. Viereck, DARCOM; and Major Lewis Samuels, AFLC.

The counsel offered by Lieutenant Colonel Joseph Arcieri, my faculty advisor, was helpful throughout the course of my research. His guidance was instrumental in lending structure and direction to the study.

Finally, my deep appreciation goes out to Ms. Gloria Grove for her interest and professional competence in the final preparation and typing of this report.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM

With the advent of wide-bodied jets such as the DC-10 and Boeing 747, commercial airlines focused a concerted effort to develop some new, systematic way of deriving scheduled maintenance requirements in a critical endeavor to reduce burgeoning operating and support costs. Following several iterations, the results of their efforts were documented in a procedure referred to as "MSG-2," or more descriptively, the Airline/Manufacturer Maintenance Program Planning Document.

Attracted by claims of significant cost reductions without notable declines in effectiveness or performance, the Department of Defense (DOD) elected to adopt the concept for revamping military aircraft scheduled maintenance requirements. Direction to that effect from DOD to the three Services appears to have been executed through rather different approaches, and it is the substance of those individual implementation programs that provides the basis for this study.

SIGNIFICANCE OF THE PROBLEM

For more than a decade, the steadily rising costs of operation and support have been of increasing concern for both airline and military aviation. The trend in the Air Force, for example, is unmistakable. In the early sixties, research, development, and acquisition of new equipment and facilities accounted for 60% of the Air Force budget. By 1968, the operating and investment shares were approximately equal. Currently, the position of the early sixties is reversed. Only 40% goes to investment,

but something approximating 60% of the total budget is needed for operation and support (20:1).[1]

The dilemma is similar for the other services. One Army assessment indicates that "approximately 80% of the total life cycle cost of a piece of equipment is expended during its operational life; only 20% is spent on the development and procurement of the item"(5).

Contrast this with what the commercial airlines have been able to achieve in the same period: "a 30% reduction in then year dollar maintenance costs per flying hour over the decade 1963-1973"(26:8).

The challenge is quite clear. Both the demands of conscientious public service and the constraints of scarce dollars for a credible defense necessitate a dramatic turnabout in our approach to support planning. "Today, when Defense spends in excess of $15 billion per year for maintenance, a fresh look at how we determine maintenance requirements is essential"(26:1).

OBJECTIVES

The overall objective of this study was to produce a document that would aid DOD, Service, and industry personnel (particularly program managers, engineers, and logisticians) in assessing the direction of reliability-centered maintenance programs for military aircraft systems. To meet this goal, the following specific objectives were pursued:

1. Explain the MSG-2 concept.

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[1]This notation is used throughout the report for sources of quotation and reference. The first number indicates the source listed in the bibliography. Where appropriate, a second number indicates a page in the reference.

2. Explore the genesis and development of reliability-centered maintenance in the commercial sector leading to its introduction in DOD.
3. Examine the various approaches taken by the Army, Navy, and Air Force in implementing MSG-2 programs.
4. Compare and contrast the three Services' approaches.

RESEARCH QUESTIONS

In an attempt to give direction to the study and to accomplish the objectives cited above, research was oriented toward answering the following questions:

1. How has reliability-centered maintenance evolved in industry, DOD, and the Services?
2. What differences characterize the approaches pursued by the Services in structuring their respective reliability-centered maintenance programs?
3. What significant lessons can be discerned through analyzing the various approaches taken by each Service?

INVESTIGATIVE PROCEDURES

Two primary research vehicles were relied upon for this study. In an attempt to gather as much primary source material as possible, a number of personal interviews were conducted with officials working in areas closely associated with MSG-2 and reliability-centered maintenance. Individuals in the Office of the Secretary of Defense (OSD), the Army, Navy, and Air Force were among those contacted.

The second major procedure involved an extensive literature search throughout Department of Defense library systems and among several libraries,

government offices, and industry associations in the greater metropolitan Washington, D.C. area. Again, emphasis was placed on using primary sources whenever possible. In an effort to secure the most current information available, correspondence and unpublished office worksheets were also used.

Research for the study was begun in July 1977 and concluded in October 1977. Unless otherwise indicated, references in the report to ongoing developments are current as of the latter date.

TERMINOLOGY

To the maximum extent possible, terms used in this study are defined in context as they appear. Several key concepts peculiar to this area warrant some initial clarification to provide a common basis of understanding and preclude fundamental misconceptions.

MSG-2 - The alpha-numeric term is really not an acronym. As originally conceived, it indicated a "Maintenance Steering Group #2." This group actually formulated the systematic decision logic approach for scheduled maintenance planning that is the subject of this study. In terms of its more familiar use today, "MSG-2" has come to refer to the actual decision logic approach rather than the original group that authored the philosophy.

Reliability-Centered Maintenance (RCM) - As the MSG-2 approach has been incorporated into the Department of Defense, it has been increasingly referred to as "reliability-centered maintenance." Purists will argue that there is in fact, some distinction in dealing with the mission profiles and scenarios unique to military aircraft operations. In the most fundamental sense, however, both terms connote a decision logic approach to scheduled maintenance planning that will capitalize, to the maximum extent possible, on the inherent reliability of systems and equipment. Recognizing that RCM

indicates the Department of Defense adaptation of MSG-2, the two terms are used interchangeably in the conceptual sense for this study.

REPORT ORGANIZATION

The report begins with an historical trace of the development of MSG-2 in commercial aviation. Also included in Chapter II is an explanation of the MSG-2 concept itself and its adoption by the Department of Defense.

Chapters III, IV, and V examine, respectively, the individual Navy, Air Force, and Army approaches to implementing OSD direction concerning MSG-2 in terms of their current programs and future plans.

Selected issues that compare and contrast the Services' MSG-2 program philosophies are discussed in Chapter VI, and resulting conclusions and recommendations complete the report in Chapter VII.

CHAPTER II

MSG-2: COMMERCIAL INCEPTION TO DOD POLICY

TRADITIONAL AIRLINE MAINTENANCE

Aircraft maintenance is a critical, integral part of commercial airline business. Because profits, as well as performance and public perceptions of safety, depend on their maintenance practices, airlines find a sizeable incentive in maintaining both economically and intelligently.

Maintenance philosophies are inevitably intertwined with equipment failures and criticality. If a particular aircraft hardware element could affect the safety of passengers, certain key questions demand answering: When will it fail? What must be done to fix it? After failure, what is the practicality of continued operation?

In this regard, the airlines have traditionally experienced a very real problem. Much of the equipment aboard an airliner is either safety-sensitive or impacts on safety of flight. Thus, for years the airlines, who could scarcely afford a breach of safety, have routinely monitored, inspected, or replaced items that provided what was generally accepted as a margin of safety (29:56).

The McDonnell Douglas DC-3, a reliable aircraft since the 1930's, provides a good example. In the early days of the DC-3, when airline and industry experts established what inspections were required and when, they had little upon which to base their judgments. As a result, the DC-3 maintenance program, and many others like it, evolved from the concept of overhaul and disassembly (7:9). That is, safety related components were periodically replaced and overhauled. The airframe was stripped and

inspected every three years (29:56). This concept appears to have worked satisfactorily for relatively uncomplicated aircraft.

It should be noted however, that traditional periodic overhaul and disassembly was accomplished in a highly conservative sense, without substantive assurance of need or proof of safety enhancement. With each subsequent generation of aircraft since the DC-3 era, systems have grown progressively more complex and sophisticated. Accompanying this increased complexity have been requirements for more highly trained personnel, and more expensive test and repair equipment.

THE DEMANDS OF SIZE AND COMPLEXITY

As aircraft grew in both size and sophistication, there came an evolving awareness that to continue maintenance programs such as that associated with the DC-3 would be not only uneconomical, but impractical as well. The overhaul and disassembly concept would keep modern aircraft on the ground up to half of their lives just for maintenance with a resultant undesirable loss in revenue. That very awareness seems to have prompted airlines and airline manufacturers to seek methods by which an airframe and its systems could define their own maintenance requirements, rather than imposing arbitrary requirements based largely upon what has been done on previous aircraft.

In the mid-1950's, when the Boeing 707 was being prepared for its first U.S. jet airline operation, operators were faced with a mandatory requirement to change their aircraft maintenance programs. The Federal Aviation Agency (FAA) established a board to review new maintenance program proposals. Thus, new proposals required justification. Airline and aircraft manufacturers established a working group to set up maintenance criteria that

would satisfy FAA requirements. While recommendations were derived mainly from experience, the criteria were also generated on the basis of laboratory test results and fatigue and static test data (6:23).

MSG-1

The introduction of wide-bodied jets like the Boeing 747 and Lockheed 1011 again posed a whole new set of problems for industry. Those aircraft were enormous, and sheer size alone demanded that some logical process be provided to select required maintenance tasks and establish the necessary frequencies at which to accomplish them. In July 1968, representatives of various airlines organized a Maintenance Steering Group (thus, the abbreviation, "MSG-1") to establish such procedures for the Boeing 747. Those procedures were incorporated in a Handbook MSG-1, "Maintenance Evaluation and Program Development" (2:1).

One Lockheed official described the significance of this document in the following way:

> These guidelines provided the first formalized breakthrough in establishing new criteria for maintenance programs. They replaced maintenance concepts that had been in use for almost 60 years (7:10).

MSG-2

The MSG-1 effort reflected the airline's strong desire for a Boeing 747 program that would reduce both down time attributable to maintenance and the costs of that maintenance, while simultaneously improving flight safety.

Those goals were by no means unique to the Boeing 747. Driven by a desire to formulate universal procedures applicable to all aircraft, a second Maintenance Steering Group (MSG-2) was formed. Building upon the

experience gained through MSG-1 and deleting details peculiar to the 747, the group produced a maintenance program decision logic generally suited to any aircraft system. The results were published in 1970 by the Air Transport Association (ATA) as the "Airline/Manufacture Maintenance Program Planning Document (MSG-2)" (2:1). Subsequently, the FAA approved MSG-2 as a reasonable and practical method for establishing new aircraft maintenance requirements, and ATA adopted MSG-2 as a standard for any aircraft undergoing development (7:11).

WHAT IS MSG-2?

Basic Description

In its most fundamental sense, MSG-2 is a decision logic: a structured, systematic procedure for establishing safe, economically sound aircraft scheduled maintenance requirements. By unstated implications, there is an underlying premise that the resultant maintenance program will be in some degree streamlined (both with regard to fewer tasks and longer interval frequency) in comparison to whatever procedures were heretofore used.

Essentially then, the MSG-2 approach relies more on logic and reliability data, rather than personal judgments, to determine what work is to be done and when. Equipment reliability forms an essential cornerstone in MSG-2 logic, but several classical notions associated with reliability, age, and maintenance have been reexamined. These are discussed at greater length in a subsequent section, but basically, airline experience and recent studies have concluded that relatively few items have an adverse age-reliability relationship within the range of their normal operating lives, and the possibility of maintenance-induced failure clearly exists (14:36). MSG-2 is founded on the notion that a reasonable maintenance program must

recognize these phenomena, and MSG-2 does this through the use of decision analysis.

The basic MSG-2 procedure begins by identifying all maintenance significant components, their functions, failure modes, consequences, and probabilities of failure. Once these components have been identified, maintenance tasks are defined that may have potential effectiveness in capitalizing upon inherent reliability or detecting degradation in reliability. Finally, the desirability of carrying out these maintenance tasks is assessed relative to the effect on safety, operational performance, or economics that the failure of such items would have.

Critical assessment of the MSG-2 concept might prompt one to prematurely characterize it as little more than systematic common sense. Clearly it is at least that. But the real crux of the problem becomes apparent with the realization that it is early in design that the logic must be effectively implemented. It has been estimated that "to fully test equipment for an entire life cycle under completely representative environments, prior to entry into service, would require that the design (and thus the technology) be at least 30 years old"(24:2). In an age when the half-life of much technology is probably something less than 6 years, this is unacceptable in terms of performance and economics alike. Thus, anything other than analogous information to optimize maintenance costs, is largely unavailable when an initial maintenance program must be developed. The MSG-2 concept seeks to provide a maintenance strategy that can directly confront the problem of decision-making with limited information.

Logic Tree

MSG-2 is structured around a series of questions and answers that are used to determine what scheduled maintenance tasks are required. The question-answer-default sequence lends itself to a decision tree such as that shown in Figure 1.

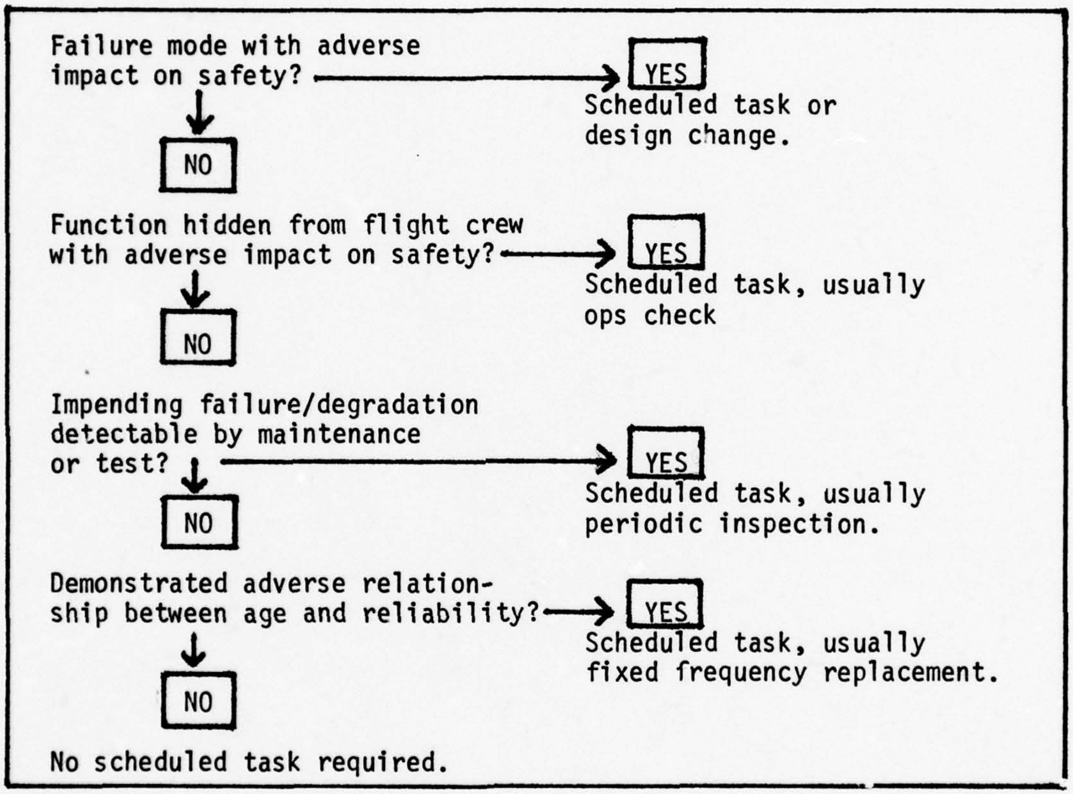

Figure 1: MSG-2 Logic Tree

Question #1 asks if a condition after failure has an adverse effect on operating safety. Based upon analysis, a "yes" answer would require an effective maintenance task or component redesign if no task could be identified. A "no" answer directs that the next question be addressed.

Question #2 seeks to determine whether failure of back-up systems that provide safety protection might be hidden from the flight crew. If so, a

scheduled maintenance task or operational check to test availability of the function is required. If not (failure is observable by the flight crew) the next question is addressed.

The objective of question #3 is to determine whether incipient failures can be readily detectable. If so, a periodic preventive maintenance task should be scheduled, if economically justified. If not, the last question is addressed.

The final question seeks to determine if there is a specific time limit before failure that can be reliably predicted. If so, a fixed interval replacement task is generally in order. If not, no tasks are required for the particular unit being considered (7:14;2:7).

Notice that the first two questions address a paramount issue: flight safety. The last two questions involve economics and therefore judgment on the part of the maintenance planner. Tasks of doubtful effectiveness should probably be avoided for economic reasons. Such tasks could certainly be selectively incorporated later if in-service experience so indicated, however. Figure 2 provides a conceptual model of the safety/economy implications of failure versus maintenance effectiveness that summarize the objectives of the MSG-2 logic tree.

		IMPACT OF MALFUNCTION	
		SAFETY	ECONOMICS
Maintenance Effectiveness	Effective	Task Required	Task Desired
	Not Effective	Redesign	No Task

Figure 2: MSG-2 Conceptual Model (7:15)

In short, the logic tree attempts to identify all tasks that "can" be done and have potential effectiveness, then segregates those that "must" be done for safety and finally those that "should" be done for economic reasons. Through this process, three categories of maintenance emerge as shown in Figure 3.

Hard Time Limit	- Maximum interval. Remove and replace
On Condition	- Periodic inspection/test to determine condition.
Condition Monitoring	- Functioning viewable to flight crew. No scheduled maintenance.

Figure 3. Failure Detection and Maintenance Categories

Hard time limit is akin to the traditional maintenance concept of fixed frequency replacement. For this case an item demonstrates a predictable reliability relationship between age and degradation. Thus, at some conservative point in time prior to predicted failure, it is removed and replaced.

On condition applies to an item for which periodic (cyclic; recurring) scheduled maintenance inspection or test can be performed to detect failure, impending failure, or degredation.

Condition monitoring is applicable to those items that are monitored by an operator's visual check or by instrumentation and gauges. Thus, no scheduled maintenance is required.

Old Tenets Challenged

The MSG-2 approach is "systematic common sense" and more. That is, under careful scrutiny, we see that it is based on axioms that depart from some long-held assumptions and beliefs held in the field of maintenance. Industry, airline, and defense participants in the evolution of MSG-2 have identified a number of former assumptions that were reviewed and essentially reversed under the MSG-2 philosophy (26:4-5). A few are recounted below.

(1) Former Assumption. Poor maintenance is the cause of safety/ reliability problems.

Result of Review. Some poor or inadequate maintenance may contribute to equipment failure, but design is more important. If the design is inherently unreliable no amount of maintenance can solve the problem. At most, effective maintenance can keep equipment operating up to the point of reliability inherent in its design.

(2) Former Assumption. More maintenance is better.

Result of Review. Any maintenance action carries at least the potential of decreasing, rather than increasing, resistance to failure. Thus, reducing the exposure of equipment to unnecessary maintenance increases its operational reliability. Every candidate maintenance task should therefore be carefully assessed to insure that it is likely to do more good than harm before it is adopted. One Air Force study showed that 40% of the work required to restore a sample of F-4's to operational condition was the direct result of failure induced by previous maintenance (26:5).

(3) Former Assumption. Equipments wear out.

Result of Review. Mr. Tom Matteson, of United Airlines, and part author of the MSG-2 concept, points out that in some ways the "bathtub

curve doesn't hold water" for complex equipment (26:5).

Figure 4 shows that traditional reliability "bathtub curve." It is true that many single component equipments such as tires, hoses, and brake pads do wear out. Complex systems composed of many single component equipments, such as radios, hydraulic systems, etc., may never "wear out" as long as the elements within the system can be repaired, renewed or replaced as needed.

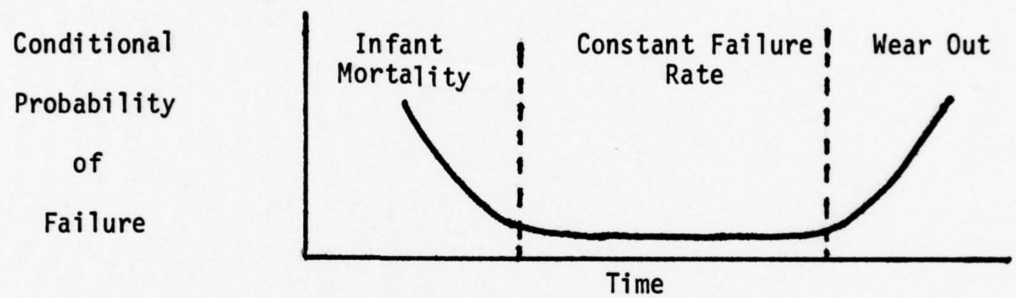

Figure 4. Bathtub Curve Correlating Equipment/Component Age vs Reliability

Probably the essential point here, however, centers on two givens: (a) there is some probability of damage inherent in any maintenance action, and (b) there are infant mortality problems associated with returning overhauled equipment to service. It follows then, that selective staggered replacement, as opposed to wholesale overhaul (and replacement of nearly every component at one time) becomes more justifiable for reasons of reliability as well as of economics.

COMMERCIAL RESULTS

The airlines have applied MSG-2 to both new and existing aircraft in their fleets. The aircraft shown in Table 1 range in age from the Boeing 707

Table 1

Percent of Airliner Components in the Various Maintenance Classes (14:45)

	Hard Time		On Condition & Condition Monitored	
	Originally	Currently	Originally	Currently
707	99	40	1	60
727	55.5	40	44.5	60
737	53	29	47	71
747	-	0.3	-	99.7
DC-10	-	2	-	98
L1011	-	2	-	98

(over 18 years old) to the relatively new Boeing 747. Contrasted are the percent of hard time limit items prescribed when the aircraft come into service, with the increased reliance on on-condition and condition monitoring today.

With results such as those shown in Table 1, the airlines claim to have realized considerable savings in maintenance man-hours and costs. For instance, airframe maintenance for the 707, which averaged $56 per flight hour in 1963, averaged only $40 in 1971 (both measured in 1963 dollars) in spite of the fact that labor pay scales and material costs had increased substantially (10:73). During the same period, the aircraft accident rate decreased (14:45).

United Airlines, a strong proponent of the MSG-2 concept, used the approach to restructure the maintenance program for its DC-8 fleet with

equally impressive results. The DC-8 depot interval was extended from 1200 to 2300 hours, time change items were reduced in number from 280 to 10 and by 1975, it reported a posture whereby, on an average, only one engine was tied up in overhaul for every 100 engines installed on its operational DC-8 fleet (27:9).

DOD ADOPTION OF MSG-2

The Department of Defense (DOD) has long been concerned with the burden of operational and support costs associated with its aircraft systems. Thus it is no surprise that the results of the MSG-2 concept in commercial airlines were attractive. In fact, Congressional staff questioning and the Office of the Secretary of Defense (OSD) interest alike gave rise to the genesis of MSG-2 in DOD (25).

Attractive as MSG-2 results may have appeared in the commercial world, there was at least some initial reluctance to adopt the approach for military aircraft. One Service contention was that military aviation operations were so different that nothing the airlines were doing to enjoy their reported success had any application to the military environment (21:48).

The Congressional budget hearings in 1974 signaled the legislature's growing intolerance for rising military aircraft maintenance costs and pointed out that each year the military was overhauling and repairing fewer aircraft than originally estimated but at a higher cost (21:48).

Fortunately, studies were underway in the Department of Defense indicating that, with minor modifications, MSG-2 procedures could be adopted by the military (14:2). The military foresaw that a decision logic reliability-based

maintenance would lead to greater efficiency for at least two reasons:

> First, it will substantiate calculations based on actual operational experience for the judgment of maintenance personnel. In doing so, it will help them avail decision making situations in which all incentives militate toward doing more maintenance than is needed. Second, by reducing the amount of time aircraft spend at the depot, it will reduce the overall aircraft procurement level needed to maintain a given level of aircraft on the line or increase the effective force level for a given procurement level and allow an aircraft to spend more of its operating life in the fleet (14:V).

Thus, in 1974 the Department of Defense adopted the MSG-2 approach as a basis for a reliability-centered maintenance program for military aircraft systems. The Defense Policy and Planning Guidance (DPPG) for that year called for restructuring the scheduled maintenance programs on existing aircraft and planning to formulate the requirements for all new aircraft using a reliability-centered maintenance concept and "the kind of decision logic which is central to MSG-2" (9:III-41). The then Deputy Secretary of Defense Clements identified MSG-2 implementation in DOD as a specific objective in his Management by Objectives tracking system (25).

Since that time, OSD has reiterated the MSG-2 policy annually, and in the 1977 Defense Guidance document it called for the Services to begin identifying MSG-2 implementation costs by specific aircraft systems in their Program Objective Memorandum (POM) submittals to OSD:

> The Services should continue to develop and implement reliability-centered maintenance strategies for all new ...(and in-service)... aircraft. The FY 79-FY 83 POMs should include and explicitly identify funds for the analysis required to develop and implement the new maintenance strategies, including a projected schedule for implementation (8:III-50).

The approaches taken by the Service thus far in implementing MSG-2 form the basis for several subsequent chapters in this report.

CHAPTER III

U.S. NAVY: MSG-2 INITIATION IN THE MILITARY ENVIRONMENT

PROGRAM DEVELOPMENT

World War II to 1970's

The U.S. Navy's maintenance philosophy appears to have evolved in a manner not unlike that seen in the commercial airlines. In the period from World War II well into the 1950's, the Navy depot maintenance concept was total overhaul. In the early 1960's, the Navy moved away from total overhaul to an interim rework concept in an attempt to reduce the depth of rework between overhaul. The interim rework philosophy evolved into the Progressive Aircraft Rework (PAR) concept. Formalized in 1962, PAR tailored rework to equipment age, and the extent of rework was based on the judgment of the maintenance engineer (7:11).

Organizational level maintenance concepts in the Navy underwent changes throughout this same era. Before 1960, intervals between aircraft maintenance checks were controlled on a flight hour basis. In the 1960's, organizational maintenance came to be based on the premise that a reasonable correlation existed between calendar time and flight hours. The implications of that correlation saw a trend toward calendar-controlled maintenance in an endeavor to more effectively control workload (7:11).

Early MSG-2 Efforts

Many Navy aircraft throughout the sixties were inspected at periodic calendar intervals under the system described above. The P-3 aircraft, for instance, was inspected every 26 weeks. There were nagging indications, however, that calendar oriented maintenance might not be the optimal

solution. In some cases, an acceptable correlation between calendar time and flight hours was either non-existant or not discernible. P-3 utilization during its 26 week period, for example, was as low as 100 flight hours for some aircraft and over 800 flight hours for others (7:11).

By the early 1970's, shortcomings in the calendar system along with growing concerns over increasing support costs prompted the Navy to explore alternative aircraft maintenance philosophies, including those in use by the commercial airlines. In 1972, Naval Air System Command (NAVAIR) requested Lockheed California Company to investigate the feasibility of adapting their L-1011 Tri Star maintenance program (MSG-2) to the Navy's P-3 Orion aircraft. These early investigations indicated that the MSG-2 planning procedure could, in fact, be used as a basis for developing an improved maintenance program for the P-3 (7:11). The resulting P-3 program is discussed at length later in this chapter.

In the ensuing two year period, OSD staff officials explored the commercial program for possible adaptability in the military. In-house studies confirmed the potential for improved maintenance under the MSG-2 philosophy. One OSD assessment indicated:

> The logic is fully applicable in the military environment. Two studies prepared by the Center for Naval Analyses . . . show a potential 50% reduction in the frequency of depot maintenance of the Navy's F-4's and a potential 53% reduction in the cost of depot maintenance of the Navy's aircraft gas turbine engines (26:8).

PILOT MSG-2 PROGRAMS

P-3 Improved Maintenance Program

The MSG-2 feasibility study for the P-3 aircraft system began in November 1972 and was formalized in 1973 as the P-3 Improved Maintenance Program (IMP). Overall objectives were to reduce scheduled maintenance and increase aircraft availability through the application of MSG-2 analytical techniques.

Program responsibility was assigned to a development team as shown in Figure 5.

Management	-	NAVAIR
Technical Analysis	-	Lockheed
Consultant	-	United Air Lines
Trial	-	Patrol Squadron 40

Figure 5. P-3 MSG-2 Development Team (7:11)

Lockheed, under NAVAIR management, formed an analysis group to develop the maintenance analysis that formed the basis for IMP. The group consisted of highly experienced former Navy and airline personnel who had firsthand knowledge of the P-3, the Navy environment, and the MSG-2 concept. United Airlines, with its extensive experience in the latter area, was hired as a consultant for the effort.

The MSG-2 analyses were tailored to accommodate the U.S. Navy's operating environment, mission scenarios, and safety requirements, although there appear to have been few significant detractions from the commercial versions. The basic conceptual algorithm for the tailoring was: Military

Considerations + Commercial Technique = IMP. Common considerations were: flight safety, mission reliability, and economics. Primary military considerations were operational environment and mission envelope (7:12).

The analyses were based on the following premises:

1. Hardware design determines inherent characteristics of safety, reliability, and maintainability.

2. Scheduled maintenance is not always effective, desirable or economical in preserving these inherent characteristics.

3. The aircraft and its components, when properly examined and analyzed, will dictate required maintenance.

4. A large percentage of aircraft components can fly-to-failure without degrading flight safety or economics (7:12).

The logic tree approach described in Chapter II was followed virtually the same as it was intended in the commercial environment.

Patrol Squadron 40, based at NAS Moffett Field, California, was designated to evaluate the program. The test began in August 1973 and was completed in January 1974. Success with the trial program then prompted the Navy to implement IMP fleet-wide on the P-3 aircraft. Total P-3 program implementation was completed in March 1975 (7:12).

Program performance results can be expected to mature in validity and associated confidence with the passage of time (and thus increased sample size). Short term results are nonetheless impressive, even by conservative standards. As summarized in Figure 6, the P-3 depot interval was changed from 36 months to 60 months. Reduced depot processing at the P-3's Naval Rework Facility, Alameda, California, has resulted in a savings of 2000 manhours per aircraft that represented approximately $3.41 million in

"cost avoidance" in FY 1976 (12:18). (The distinction between "cost avoidance" and "savings" is discussed in Chapter 6; conceptually, at least, "cost avoidance" may be reasonably thought of in the same context as the more widely understood term, "savings"). Elimination of the Functional Check Flight requirement following P-3 phase inspections produced additional savings of $28,000 (12:18).

Depot Interval Extended (36 to 60 mos)

Depot Savings

- 2000 manhours
- $3.41M in FY 76

FCF's eliminated after Phase Insp. ($28K/phase)

Figure 6. P-3 MSG-2 Results (12:18)

S-3A Program

The P-3 program was intended to demonstrate whether or not the MSG-2 process could be successfully applied to in-service Naval aircraft. Alternatively, an effort was needed to determine if the approach was similarly suitable to a new procurement Naval aircraft, such as the S-3A.

A contract was awarded to Lockheed California Company in May 1972 to develop scheduled maintenance requirements for the S-3A. Again, Lockheed used airline consultants in their study and realized such attractive savings as a 50% reduction in maintenance manhours (compared with the requirements expected from conventional strategies) (14:46).

Of the more than 1500 structural items and components considered, 496 were determined to be maintenance significant by use of the MSG-2 logic tree.

Of these, 335 fell into the condition monitoring class, 137 into on-condition, and only 24 into hard time fixed replacement. The study also showed that approximately 90% of the S3-A critical structural items provided external evidence of degradation. Thus, continuous monitoring of their integrity without depot inspection was possible (14:47).

The S-3A study was equally encouraging, then, in terms of feasible MSG-2 application for new system acquisitions. While the data base of actual field results in thus far considerably more limited than that of the P-3, Tables 3 and 4 in the next section show evidence of favorable, tangible benefits already.

CURRENT AND PLANNED EFFORTS

Analytical Maintenance Program

Motivated by early experience, successful MSG-2 pilot programs, and unmistakable OSD guidance and direction, the Navy has adopted MSG-2 as the basis for all of its aircraft scheduled maintenance planning. Formalized under the name "Analytical Maintenance Program" (AMP), it is intended to eventually encompass all existing and future Naval aircraft systems. Rear Admiral Faulders' assessment of the program confirms that intent:

> The scope of AMP coverage today is quite extensive. The objective is to have all front line aircraft operating under redefined maintenance programs by Fiscal Year 1980 (12:18).

Table 2 shows Navy aircraft planned for AMP implementation through 1980. It should be noted that, in addition to those projected, P-3, S-3, and F-4 aircraft are now operating under AMP.

Table 2

Navy Aircraft Planned for

MSG-2 (AMP) Implementation (12:19)

1977	1978	1979	1980
A-7	F-14	OV-10	C-130
E-2	A-6	H-2	H-1
T-2	AV-8		H-3
	A-4		H-53
	H-46		

The recently completed F-4 program analysis has been equally encouraging and can be expected to confirm the impetus for continuing AMP application as programmed. Table 3 shows the F-4J depot rework interval extended from 30 months to 36 months, along with similar figures from the P-3, S-3, and J-79 engine.

Of equal significant to the extended depot intervals is the realization that actual processing effort when aircraft finally arrive at the depot for rework has been reduced (i.e., work is not merely being delayed and accumulated). Table 4 shows actual depot maintenance costs reduced by as much as 37% over those before AMP application.

Preliminary analyses on aircraft systems programmed for AMP in the years ahead are equally encouraging, and possibly even conservative. Table 5 shows predicted depot interval extensions of 8% for the OV-10 (programmed for 1979). 25% for the F-14 (1978) and 20% for the A-7 (due to be completed later this year).

Table 3

Actual Changes in Depot Intervals (21:106)

Acft/Eng	Before	After	Improvement (Extension)
P-3 (Acft)	36 mos	60 mos	67%
S-3 (Acft)	24 mos	36 mos	50%
F-4J (Acft)	30 mos	36 mos*	20%
J-79 (Eng)	1200 hrs	2400 hrs	100%

*Actual interval is 960 flight hours; based on current utilization, this equates to 36 months

Table 4

Comparative Actual Annual

Depot Maintenance Costs (21.124)

Acft/Eng	Before	After	Improvement (Reduction)
P-3 (Acft)	$23,840,880	$16,808,400	29%
S-3 (Acft	8,865,840	5,628,480	37%
J-79 (Eng)	15,477,429	11,047,773	29%

Table 5

Predicted Changes in Depot Intervals (21:108)

Acft	Current (mos)	Predicted (mos)	Improvement (Extension)
F-14	24	30	25%
A-7	30	36	20%
OV-10	48	52	8%

"In-House" Orientation

While initially relying upon contractors like Lockheed and the consultant services of United Airlines, the Navy appears to have exhibited a certain proclivity toward establishing an "in-house" capability for performing MSG-2 analyses within the context of its Analytical Maintenance Program. Even during the early P-3 IMP effort, a transition team was established to provide fleet-wide indoctrination, training, and a clear understanding of the MSG-2 philosophy to all P-3 squadron personnel. When the P-3 IMP was completed in March 1975, 45 activities had received training (7:12).

Since that time, Navy personnel have become increasingly involved with each succeeding MSG-2 program application. Conversely the trend indicates less and less reliance upon contractor performance of the analyses.

The Navy's orientation to an "in-house" AMP is reflected by RADM Faulders:

> Navy engineers and technicians have greatly improved their technical knowledge of Naval

> aircraft after completing the in-depth engineering analysis ... (We have learned not to) become too dependent on contractors to apply Reliability-Centered Maintenance to (our) equipment. If your people don't understand and support it, they can't sustain it (12:19).

Further evidence of the desire to sustain that commitment and associated capability lies in the formal AMP training program administered by NAVAIR. Structured in 4 sessions, the training program is a detailed, comprehensive treatment of the MSG-2 background, concept, and analytical application (21:Appendix).

CHAPTER IV

U. S. AIR FORCE MSG-2 PROGRAM

The Air Force has undertaken numerous maintenance improvement efforts over the years, but the Navy's P-3 MSG program appears to clearly predate any formal USAF endeavor to incorporate MSG-2 procedures. A combination of commercial success, favorable Navy results, and OSD guidance, prompted the Air Staff to formulate plans for a comprehensive Air Force program to incorporate the MSG-2 philosophy into all USAF aircraft scheduled maintenance.

MAINTENANCE POSTURE IMPROVEMENT PROGRAM

In September 1974, the Office of the Chief of Staff, USAF, issued a Program Management Directive (PMD) creating an Air Force Maintenance Posture Improvement Program (MPIP). Overall objectives were to significantly "reduce maintenance costs (manpower and material) and increase effectiveness" (15:1).

Initially, the program was limited to analyzing and revising the maintenance inspection requirements and organizational support structure for 5 aircraft systems (F-106, T-38, C-141, B-52 and F-4). In addition, Air Force Logistics Command (AFLC) was asked to review its Maintenance Manager Review Program (MMRP) (15:2).

While MSG-2 was not explicitly mentioned in the main body of the PMD (the ATA MSG-2 document was among the references cited in a bibliography attached to the PMD), many of the tasks to be examined clearly reflect its influence:

> ...review and analyze all scheduled inspection requirements for validity of need, frequency, and scope, with the aim of eliminating tasks, reducing the frequency of inspection...without compromising safety or operational mission capabilities.
>
> ...review and analyze all time change items for possible deletion...or extension.
>
> ...review and analyze methods and procedures used for scheduling maintenance (15:2).

While the initial MPIP effort was limited to the 5 aircraft systems mentioned above, the PMD contained plans for a far more comprehensive effort:

> Ultimately, the program will encompass all USAF systems and equipments as well as conceptual, development, acquisition, and modification policies, procedures and practices which affect maintenance requirements and cost (15:2).

AIR STAFF MSG-2 DIRECTION

Later in 1974, the Air Staff sent specific, expanded direction to Air Force Logistics Command (AFLC) and Air Force Systems Command (AFSC) to use MSG-2 as the basis for all aircraft scheduled maintenance planning. Correspondence from Maj Gen Hayes, then Air Staff Director of Maintenance Engineering and Supply, indicated:

> We have looked at the Navy's application of MSG-2 and are convinced that it has a truly significant payoff. In consonance with DPPG directives, plans are being made and funds are being programmed to back the MSG-2 approach into operational aircraft (4:1).

AFSC IMPLEMENTATION

On 11 December 1974, the Air Staff sent formal direction to AFSC to implement the use of MSG-2. Included in the tasking letter was a request to:

> Advise all current SPO's for aircraft scheduled to become operational in FY 77 and beyond of the existence of MSG-2 and of the need to apply the MSG-2 approach...and apply the MSG-2 approach to other aircraft currently in acquisition for which AFSC has engineering responsibility (4:1).

AFSC's initial action to implement MSG-2 was briefed to the Air Staff at an MPIP conference in March 1975. For purposes of applying MSG-2 to aircraft systems in various stages of the acquisition process, three categories were identified: (a) those aircraft where MSG-2 had already been used to formulate the system's scheduled maintenance program, (b) those aircraft where conventional scheduled maintenance planning had already been completed or was substantially underway to the extent that the effort would need to be wholly reaccomplished, and (c) those aircraft where definitive scheduled maintenance planning was not yet so far advanced that MSG-2 could be incorporated at the appropriate time in system development (1). The systems so identified in those initial categories are shown in Figure 7.

MSG-2 Used	Conventional Techniques Used; Reaccomplishment Using MSG-2 required	Will use MSG-2 at appropriate stage in development
AABNCP (E-4) AWACS (E-3)	A-10 F-15 F-5 A-37 F-4E	B-1 F-16 AMST ATCA All future aircraft systems

Figure 7. AFSC initial MSG-2 categorization of Aircraft Systems (1).

The E-3 and E-4 systems cited in Figure 7 each have basic commercial airframes, the Boeing 707 and the Boeing 747 respectively. It was thus not

surprising to find that the MSG-2 commercial airline concept had played a substantial role in developing their scheduled maintenance programs. The E-4 had already used the MSG-2 concept. The E-3 was in the final stages of reaccomplishing its maintenance program using MSG-2 on the basis of a proposal by Boeing Company and agreements among the Program Office, Tactical Air Command, and AFLC.

That category of aircraft systems where more conventional maintenance planning methods had already been accomplished created some problems. The additional costs of reaccomplishing the maintenance programs and associated technical data had to be funded within the constraints of ever scarce research and development money. The A-10 and F-15 programs were particularly affected. The Fairchild estimate for reaccomplishing the A-10 scheduled maintenance program was initially set at $800,000. McDonnell-Douglas estimated $2 Million for the F-15 effort. The A-37 and F-4 programs were transferred to AFLC, and AFSC recommended against contract and reaccomplishment of the F-5 maintenance program based on the limited size of planned USAF inventory for that system, and high contract costs versus anticipated benefits (3:1).

In the past two years, AFSC implementation of MSG-2 on aircraft systems has continued. General Dynamics is examining the concept for the F-16, and the requirement will likely be placed formally on contract in late 1977. The AMST (Advanced Medium STOL Transport) has included the requirement in its program plans. The A-10 and F-15 programs have planned funding for MSG-2 in FY 78. Figure 8 summarized the current status of MSG-2 implementation in AFSC.

MSG-2 Previously Incorporated	MSG-2 Underway or Planned for the Immediate Future	MSG-2 Future Plans
E-3 E-4	A-10 F-15 F-16 AMST	All future aircraft systems

Figure 8. AFSC Current Status of MSG-2 Implementation (27).

The use of MSG-2 has become a matter of AFSC policy for all future aircraft systems. The latest AFSC supplement to AFR 66-14, Equipment Maintenance Policies, Objectives, and Responsibilities, contains the following requirement:

> For new aircraft systems' scheduled maintenance criteria, the decision logic contained in the Airline/Manufacturers' Maintenance Program Planning Document (MSG-2) or MIL-M-5096D (after MSG-2 is incorporated) will be used to develop aircraft scheduled maintenance requirements for the 6 technical order (11:1).

The military specification (MIL-M-5096D) cited above is the contractual document (authored by USAF, though technically available for use by any Service) used to guide a contractor in his development of scheduled maintenance requirements. The specification has since been amended and now contains MSG-2 requirements (16:1-20).

For the foreseeable future, AFSC implementation of MSG-2 on each new aircraft system is likely to be accomplished through contractual effort, most probably that of the system prime contractor during development.

AFLC IMPLEMENTATION

AFLC was similarly tasked by the Air Staff in 1974 to implement MSG-2 on all operational aircraft systems The AFLC program likewise evolved as part of the overall MPIP program and now includes plans to expand applications on other than aircraft systems.

Maintenance Management Review Program

AFLC has, for some time, employed a Maintenance Management Review Program, intended to periodically assess the effectiveness of aircraft scheduled maintenance tasks. Using both operational field data and senior non-commissioned officers with actual system experience, the objective of the program was to delete or extend inspection requirements where lack of failures so indicated, or conversely, to make more stringent the maintenance requirements on the components or subsystems failing more often than anticipated.

There were at least two problems with the program. First, as discussed in Chapter 2, the remedy for failures may not necessarily be increased interval frequency inspection. Second, actual MMRP results indicated that many reviews resulted in adding more requirements rather than producing an overall net reduction (23). Among the reasons that might be speculated for this phenomenon: (a) depot manager motivations to protect depot workload and (b) a tendency to focus on "problem" components and subsystems.

It should be noted that the intent of the MMRP was oriented toward streamlining scheduled maintenance requirements on the basis of actual field experience and failure data. The objectives were not unlike those of MSG-2 or MPIP in general. It could, in fact, be questioned why the basic MMRP

approach might not have been an effective vehicle for improvement under the high level management emphasis given MPIP. In any event, the MMRP was eliminated in the early days of MPIP and AFLC turned its efforts to a new MSG-2 program.

Initial MSG-2 Application: B-52

AFLC's first major implementation of MSG-2 was on the B-52 system under contract with Boeing. Funded in fiscal years 1976 and 197T, the contract cost was $130,000 (18:1).

Results of the B-52 MSG-2 analysis appeared quite favorable. The study indicated that B-52 organizational and intermediate inspection requirements would be significantly reduced (over 700,000 maintenance manhours reduction) (19). With projected savings of such magnitude, it was virtually inevitable that the Strategic Air Command (SAC) would come under severe pressure to conduct a manpower study and adjust manning authorizations after some verification period of actual demonstrated experience on the B-52 under the streamlined maintenance requirements. Before such a validation occurred, however, OSD directed a reduction of 864 maintenance spaces from SAC, apparently based on confidence that the projected increased effectiveness would, in fact, be realized (19).

Aircraft and Equipment Application

AFLC has outlined a comprehensive program to reaccomplish the scheduled maintenance programs on nearly all operational aircraft systems in the USAF inventory. Table 6 shows those aircraft and engines either completed or planned with funding in FY 76-77. It is noteworthy that, in most cases, the

Table 6. AFLC System/Equipment MSG-2 Status for FY 76-FY 77 (18:1-4)

Fiscal Year Funded	System Equipment	Contractor	Cost	Remarks
76/7T	B-52	Boeing	$130,000	
	C-130	Lockheed	553,161	
	C-141	Lockheed	407,000	
	KC-135	Boeing	434,000	
	F/FB-111	General Dynamics	790,000	
	T-38	Vought	297,362	
	C-5	Lockheed	450,000	
			$3,061,523	
77	H-3	Sikorsky	$329,000	
	H-53	-		Contract in negotiation late in FY 77
	F-106	Information Spectrum	576,973	
	OV-10	Vought	334,896	
	T-37	Vought	281,200	
	J-85	-	-	Intermediate part of T-38 Depot to be done organically
	T-56	-	-	Organic using Navy data
	T-39	Rockwell	580,000	
	F-4	-	-	Organic effort using Navy data
	A-7D	Vought	372,832	
	J-79	Gen Electric	112,871	
	J-57	-	-	Award to be determined
	TF-34	-	-	Contract actions underway
	J-69	-	-	Organic effort
			$2,587,772	

MSG-2 analysis is being done almost entirely by contractual effort at a total cost in excess of $5.5 million (18:1-4).

Beginning in 1977, however, there is some evidence of attempts to accomplish the work organically, and, for systems like the F-4, to make use of MSG-2 analytical data available from the U.S. Navy. There are, however, still some instances of apparent overlap. Table 6 shows the A-7 MSG-2 analysis being performed for AFLC by Vought at a cost of $372,832 even though the Navy has already completed an analysis on the system.

Table 7 outlines all systems and equipment programmed for MSG-2 application through FY 78. The latter fiscal year, in particular, shows a growing intention to perform more and more system analyses "in-house." The trend becomes unmistakable when long range MSG-2 plans are seen. Table 8 shows those systems and equipment programmed for MSG-2 in FY 79 through FY 81 as being accomplished almost entirely through organic engineering capabilities. Technical Services in each of the Air Logistics Centers would appear to be an organization where such capabilities may exist already.

The Air Staff MSG-2 project officer confirms that this trend is no accident. The desire at that level is explicit that the AF should evolve from contract to organic in its approach to implementing MSG-2 (13).

Another interesting trend shown in Tables 7 and 8 is the intent to apply the MSG-2 concept to equipment other than aircraft and engines. Beginning in FY 78, prototype efforts on support equipment (SE) and electronic countermeasures (ECM) equipment, for example, are programmed.

The AFLC program approach has recently been documented in an AFLC Pamphlet 66-35, "Scheduled Maintenance Requirements Analysis," to be published in the immediate future (24:1).

Table 7. AFLC Current and Near-Term MSG-2 Applications (18:5)

FY 76/7T		FY 77		FY 78	
B-52	(C)	H-3	(C)	TF 41	(C)
C-130	(C)	H-53	(C)	TF 33	(C)
C-141	(C)	F-106	(C)	ODD-135	(C)
KC-135	(C)	OV-10	(C)	J 60	(N/O)
F/FB-111	(C)	T-37	(C)	J 75	(C)
T-38	(C)	J-85	(C/O)	T 76	(N/O)
C-5	(C)	T 56	(N/O)	T 64	(C)
		T-39	(C)	T 58	(C)
		F-4	(N/O)	O-2	(O)
		A-7	(C)	A-37	(O)
		J 79	(C)	GTCP 165-1	(O)
		J 57	(C)	GTCP 180	(O)
		TF 39	(C)	GTCP 397	(O)
		J 69	(C/O)	T 400	(N/O)
				UH-1N	(C)
				UH-1F(P)TH	(C)
				C-123	(C)
				SMFOP Train	(C)
				F-5E/F	(O)
				J 85-21	(O)
				AGM 65 (Prototype)	(O)
				CEM (Prototype)	(C/O)
				SE (Prototype)	(C/O)
				ECM (Prototype)	(C/O)
				C-9 (Data)	(C)
				T-43 (Data)	(C)
				SMFOP Test	(C/O)

(C) - Contract
(O) - Organic
(N/O) - Use Navy data and work organic

Table 8. AFLC Long Range Plans for MSG-2 Application (18:5)

FY 79		FY 80		FY 81	
TF 30	(C)	C-140	(C/O)	AIM 7F	(O)
T-43	(C/O)	AIM9J/L	(O)	AGM 78D	(O)
C/VC-9	(C/O)	LGM 25	(C/O)	AGM 88	(O)
GTC85-71	(O)	C-12	(O)	Train. Equip.	(O)
T62-T-32	(O)	AQM/BQM-34	(O)	AIM/AGM Misc.	(O)
T41M9	(O)	Sup. Equip.	(O)		
C-7	(O)	CEM	(O)		
AGM 69A	(O)	BGM-34	(O)		
ADM 20	(O)				
LGM-30	(C/O)				
AIM9E	(O)				
ECM Pods	(O)				
Sup. Equip.	(O)				
CEM	(C/O)				

(C) - Contract
(O) - Organic

Training

To achieve a posture whereby AFLC will indeed possess a credible capability to perform MSG-2 analyses organically obviously requires a sizeable training program. In September 1976, AFLC contracted with Information Spectrum at a cost of $77,500 to formulate and conduct an initial training program. A 4-hour orientation course was taught at HQ AFLC in March 1977 and 60-hour detailed analysis courses were taught at each of the Air Logistics Centers throughout the spring and summer of 1977 (17:3).

AFLC is now working with the Air Force Institute of Technology in attempting to set up an ongoing training program for both AFLC and other major Command personnel (23).

CHAPTER V

MSG-2 IN THE U.S. ARMY

The Army appears to have been the last of the three Services to formally incorporate the MSG-2 concept in its approach to scheduled maintenance planning. It may only have been last in the most formal sense, however, since much of the Army's maintenance program in the early to mid-1970's seems to have actually contained a good deal of the conceptual basis for the more structured MSG-2 decision logic.

ARMY MAINTENANCE PROGRAM EVOLUTION

Vietnam Era

Under the traditional concepts of aviation maintenance, high flying hour operation of helicopters in Vietnam required frequent replacement of time-changed components. Aircraft maintained under the conventional flying hour overhaul concept were returned to the United States for depot overhaul at ever increasing rates (29:57).

Faced with the challenge of keeping equipment operating, Army engineers developed a new maintenance concept based on analysis of failure data for components returned for overhaul. Failure profile studies of selected safety-sensitive components segregated items into three categories, each with associated inspection concepts: (1) sudden/random failure -- low inspection payoff, (2) rapid wearout failure -- moderate inspection payoff, and (3) slow wearout failure -- high inspection payoff (29:58).

Under this three category failure analysis concept, the Army successfully reduced or eliminated many time change items and inspection requirements. Random failure items (e.g., electronic radios) were seen as offering no opportunity for prediction of failure. In those cases, design redundancy appeared to offer an alternative to minimize the effect of failure. Parts with rapid wearout characteristics were candidates for condition monitoring, although, due to the high rate of wear, many were replaced at timed intervals in conjunction with other required maintenance whenever possible. Those components with slow wearout characteristics appeared to be in the majority and afforded the best potential payoff for time spent in inspection for condition. The net result was that an aircraft was no longer returned to the United States for overhaul simply on the basis of hours flown. It was first inspected for condition in the field, and, if possible, selected component replacement made possible the deferment of overhauls.

A key to the categorization process described above was somehow discerning a point of impending failure and then identifying the time from that point to the actual failure. The Army concept for this critical analysis centered on determining the Time from Onset (TOS) of deterioration to actual failure. This was essentially the time during which a component could be detected as deteriorated and thus, the time during which inspection might be effective. It was this direction of component failure analysis that led to the more familiar Failure Mode Effects and Criticality Analysis (FMECA) as Army maintenance concepts evolved through the early 1970's (5).

Integrated Logistics Support

By 1974, the Army had formalized its maintenance planning concepts into

two broad categories: (1) for aircraft in development - Integrated Logistics Support, and (2) for aircraft in operation - Logistics Maintenance Management (5).

Integrated Logistics Support was, of course, not new to either the Army or the Department of Defense. The concept had been evolving throughout the decade of the sixties and enjoys support throughout DOD to this day. In the face of increasing OSD pressure to formally incorporate MSG-2 concepts into Service scheduled maintenance planning, however, the Army appears initially at least to have clung to ILS as an alternative approach. It is unclear as to why the two were thought of as alternatives rather than one as a compatible subset of the other. Nonetheless, the argument existed for a time, although probably more in semantics and terminology than substance. As late as 1975, an Army briefing on the subject noted:

> The Army appreciates the importance of the type of strategy included in the MSG-2 document.... We feel that our maintenance logic contained in the Integrated Logistics Support Plans for aircraft in development better meets our need and implements reliability centered maintenance concepts on such aircraft (5).

Notwithstanding the semantic differences, it appears that the Army had, in fact, evolved its philosophy toward something closely approximating MSG-2. The cornerstone of its ILS approach for aircraft in development was the Logistics Support Analysis which the Army was beginning to call a "reliability centered maintenance analysis." It began with a comprehensive Failure Mode Effects and Criticality Analysis (FMEA), examined maintainability growth curves, and incorporated a maintenance tear down and analysis review. The failure mode and effects analysis, of course, is the same basic foundation required for the MSG-2 approach. Similarly, the Army approach employed an

ILS Management Team consisting of contractor and Army personnel to determine the best ways to support and maintain the aircraft. Once again, it was recognized that this team was "comparable to the MSG-2 Steering Group composed of representatives from operators, prime airframe, and engine manufacturers" (5).

Results under the Army's program indicate successes comparable with those experienced by the other Services. By early 1977, at the Society of Logistics Engineers Maintainability Symposium, they were able to report:

> Field life of engines in the UH-1 helicopter have thus been progressively increased from 200 to 1800 flight hours in the past five years.... Implemented as Project INSPECT in the Army's Huey fleet, aircraft are flying more hours with less inspection time. The old 100 hours for the periodic inspection cycle...has given way to 800 hours...25-hour periodics are no longer required. In a conjunctive program for airframe inspection, Aircraft Condition Evaluation (ACE), inspections have all but eliminated the need for periodic overhauls (29:58).

FORMAL INCORPORATION OF MSG-2

Decision Logic

While it is clear that a great deal of the maturing Army maintenance philosophy closely approximated the MSG-2 approach, the systematic structured decision logic remained a notable omission. One OSD staff paper noted:

> The (MSG-2) logic is fully applicable in the military environment.... The U.S. Army Air Mobility Research and Development Laboratory independently appears to have arrived at much

> the same point of view. Their studies of which the rest of the Army seems unaware, have shown the full applicability of these principles to helicopters, and potential savings and safety and operational improvements greater than the Navy's studies (26:8).

Undoubtedly prompted by top OSD management interest in this area, the Army elected to conduct a reevaluation of its scheduled maintenance planning program. The effort was monitored by a high level steering group, and policies, regulations, and documentation were analyzed. The study confirmed the existing system to be adequate except in the area of formalizing the decision logic. As a result:

> A major project has been initiated by the Army's Development and Readiness Command (DARCOM) to apply formal RCM decision logic to all major equipment systems.... Using the MSG-2 decision logic as a basis...(29:59).

Current Status

By the fall of 1977, the Army's program to formally incorporate MSG-2 was well underway. Reliability-centered maintenance terminology is apparent throughout their program's description. Confirmation of their earnest intent to adopt the approach in both name and substance is particularly evidenced by their decision to have an independent evaluation conducted of the entire Army scheduled maintenance program. DARCOM has contracted with Martin-Marietta to undertake a comprehensive analysis of their program and its effectiveness in employing RCM concepts. Industry, airline, and other Service experience in this area will be included along with a critical assessment of the internal Army program with recommendations for improvement. Martin-Marietta was selected sole source on the basis of its combined experience with Army system support, Logistic Support Analysis, and RCM (28).

Progress briefings and government-contractor interaction will occur throughout the effort and a final report is expected in 1978.

The Army has also formalized MSG-2 policy guidance internally. AR 700-127, ILS, now includes a specific requirement for RCM logic to be incorporated in design.

In November 1977, a conference of all DARCOM Directors of Maintenance is scheduled to be held in St Louis. Express purpose of the meeting is to discuss current and future directions of the DARCOM RCM program.

Incorporation of the RCM philosophy on Army aircraft can probably best be described as evolutionary. DARCOM management believes (and the evidence appears to support their contention) that at least some of the RCM philosophy has been included in their maintainability design, ILS, and LSA programs (under names other than RCM) since the early 1970's. Figure 9 summarized the status of Army aircraft RCM applications for both in-service and development aircraft. Kaman Associates is under contract to reassess the scheduled maintenance concepts for major in-service aircraft systems.

In-Service		Development		
Complete	Underway	U-60	AAH	CH-47D
UH-1 CH-47	AH-1 U-21 OV-1 OH-58	(UTTAS)		(major mod program)
Kaman Associates		Sikorsky	Hughes	Boeing Vertol

Figure 9. Army Aircraft RCM Applications (28).

Preliminary results are encouraging. DARCOM estimates it saved $47 million in 1975-1976 through reduced overhaul requirements (28). Culminating a series of Army maintenance improvement programs and the recent Kaman Associates effort, the T53 engine (UH-1) average overhaul interval has grown from only 200 hours in 1962 to 1800 hours in 1977. In fact, the whole concept of helicopter scheduled airframe maintenance has changed significantly. Hard time limit overhauls have been replaced with visiting teams periodically inspecting aircraft at operating sites "on condition" to determine when depot maintenance is required. While the implications for increased system availability are evident, it may be necessary to reexamine the excess depot capacity resulting from the reduced overhaul work load. DARCOM is, in fact, now dealing with the possibility of a rather severe reduction at one of its two aviation depots: Corpus Christi and New Cumberland (28).

The Army has also been active in extending the RCM philosophy into non-aeronautical equipment areas, particularly combat vehicles. Tank Automotive Readiness Command has undertaken a program to eliminate mileage as a hard time limit criteria, although even under that system they have been successful in extending the M113 Armored Personnel Carrier interval from 5000 to 6500 miles. In FY 78, all M60 series tanks in CONUS will be overhauled "on condition," as opposed to mileage hard time limit, as a pilot project. If successful, it is the Army's intent to convert depot maintenance on all combat vehicles to an on-condition basis by FY 79 (28).

Formal RCM training at this point is limited to several hours at the Army's one-week project management course conducted at Fort Belvoir. This may be one area where program expansion is possible.

CHAPTER VI

COMPARING THE SERVICES' APPROACHES TO MSG-2

The preceeding chapters were intended to provide both a descriptive and analytical examination of how each Service has implemented OSD direction to incorporate reliability-centered maintenance concepts in their scheduled maintenance planning programs. Throughout the individual analyses, a number of issues affecting all three Services become discernible - some that they have dealt with similarly; others quite differently. In an effort to consider these areas of contrast in some greater depth, several points have been selected for further discussion.

NEW VS IN-SERVICE AIRCRAFT

Each Service has dealt with a recognition that some distinction is possible in reliability-centered maintenance planning for new versus in-service aircraft. Part of the distinction lies in the fact that, for new development aircraft, only limited laboratory and test program reliability-data is available on which to base maintenance program content and interval. A thorough failure mode and effects analysis and structured decision logic process provide invaluable tools under these circumstances. In-service aircraft, on the other hand, have the additional feature of a field use data base with failure data characterizing experience with the system in actual use.

The Navy program recognizes that, for new aircraft, many potentially expensive scheduled maintenance requirements can be avoided by properly designing the hardware to begin with. To make that recognition effective, however, requires a closely disciplined feedback process. For in-service aircraft, where design modification funds are limited, the alternative generally involves optimizing economical scheduled maintenance around the maximum reliability inherent in the existing equipment. Their 3M Maintenance Data Collection System provides an important input for this effort. The Navy version of MSG-2 for in-service aircraft has been published in NAVAIR Management Manual NA-00-25-400. The decision logic for new procurements is contained in Aeronautical Specification 4310 (12:18).

The Air Force program appears to deal with the distinction similarly. AFLC Pamphlet 66-35 stresses that the engineering analyses for in-service aircraft must incorporate Material Deficiency Reporting data and information from the Maintenance Data Collection System (24:2). For new aircraft, the Air Force has amended its military specification, MIL-M-5096D, to incorporate the MSG-2 decision logic almost in its entirety.

Finally, the Army has also distinguished its approaches to new and existing aircraft through ILS and Logistics Maintenance Management, respectively. As discussed in Chapter V, the ILS, LSA approach for new systems was founded on the necessary FMECA and has since been expanded to include a structured decision logic. Their program for aircraft in operation, through such efforts as Project INSPECT, seeks to capitalize to the maximum extent possible, on reducing depot requirements and exploiting on-condition maintenance.

ORGANIC VS CONTRACT EFFORTS

The Navy RCM program (AMP) was the first to become heavily "in-house," oriented (22). Even in their P-3 pilot effort, government engineering and squadron personnel were made an integral part of the team effort. While today, consultants are selectively used, the overall Navy program is clearly more organic than contract.

As the data in Chapter IV reflects, the initial Air Force program was heavily contract oriented. Plans for FY 78 however show many more system analyses being accomplished organically, and succeeding year programs are to be almost exclusively in-house.

The Army program for aircraft is currently contract oriented, but considerable in-house expertise in RCM is beginning to develop. For other commodities, much of the analytical work is being done organically.

In each of the Services, a discernible trend begins to emerge in the area of contract versus organic analyses. In the infancy of their respective programs, an agency seems to rely heavily upon contractors. As it evolves, a mix of organic effort appears in conjunction with industrial consultants. In the later stages of program maturation, as organic expertise develops, the preference seems to swing more heavily to in-service analyses.

TRAINING

As the Services move toward developing the kind of organic expertise in MSG-2 discussed above, each has recognized the need for RCM oriented training programs.

The Navy has developed a comprehensive 4-phase orientation course in

MSG-2. The Air Force has been through one phase of contractor conducted training and is currently working to establish an ongoing AFIT program in RCM. The Army training program is probably smallest in scope at this point, but some formal instruction in MSG-2 is included in their course for project managers.

RCM training would appear to be a prime candidate for triservice cooperation. Already, there has been some duplication of effort, and the potential for savings through some common endeavor seems high.

"SAVINGS" VS "COST AVOIDANCE"

As each of the Services has applied MSG-2 to in-service aircraft systems, results, in varying degrees, have been favorable. That is, increased system availability, reduced maintenance downtime, decreased inspection requirements, or some mix of these has been observed. Clearly, this sort of outcome is desirable; it is in fact, what we are striving for.

Alternatively, the critical question may now be raised: In the face of these reduced maintenance requirements, will we now divest ourselves of excess field and depot capacity or maintenance manpower? This is the crux of the problem. Managers traditionally balk at manpower cutbacks particularly in a maintenance environment that they have characteristically regarded as "overworked." Nonetheless, Congress and OSD alike will undoubtedly address the issue. The SAC B-52 case discussed in Chapter IV indicates one OSD directed manpower cut in excess of 800. The Army is currently considering a dramatic cutback at one of its aviation depots.

One interesting outgrowth of this dilemma is the increasingly frequent use of terms like "cost avoidance" in place of "savings" to describe the

results of system RCM application. While there is a legitimate distinction, the former term is being misused to some extent. It would appear that there is some tendancy to more carefully guard any dramatic predictions of reduced work load until results can actually be validated. The tendency is undoubtely strengthened by such other factors as the potential for detrimental effects on budget justifications and the desire to divert saved dollars to other needed areas previously denied sufficient funding.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

1. All three Services appear to be moving in earnest to implement the MSG-2 or RCM approach to scheduled maintenance planning.
2. Military adoption of the MSG-2 approach has incorporated the commercial logic version virtually unaltered. Minor compensation has been made for differences in military mission profiles with some tailoring for in-service versus development aircraft, but the basic commercially originated technique is still recognizable.
3. As the military department RCM programs evolve, there appears to be a trend of initial heavy reliance on contractors to perform the MSG-2 analyses. As programs mature, the tendency is to move toward a mix of organic/contractor consultant or wholly organic effort.
4. The tendency or desire to eventually rely more heavily upon in-house capabilities has driven each of the Services to establish formal RCM training programs.
5. Individual service RCM programs have resulted in some duplication of effort within DOD. The Navy and Air Force have exchanged data on a number of common systems, but a few individual analyses on common systems have also been undertaken. Service training programs in RCM seem to provide an even more apparent area of overlap. Individual training programs are either in being or currently under development.
6. Favorable MSG-2 application results (reduced requirements) are bringing increasing pressures on the Services to divest themselves

of excess manpower and depot maintenance capacity.

7. Each Service has begun (or is planning) to delve into extending the MSG-2 philosophy to non-aeronautical systems and equipment.

Early in the course of this effort, it became apparent that only a moderate amount of research had been undertaken in the area of MSG-2 concepts applied in the military environment. A number of areas have been left virtually unexplored. Many could have significant impact on program costs. In this context, I have suggested several issues that should be prime candidates for further research or examination:

1. As the results and lessons of MSG-2 application to in-service aircraft are validated, some structured technique to feedback this knowledge into the design engineering process would be highly desirable. General corporate memory is undoubtedly of some help, but a systematic mechanism for considering failure mode consequences and associated maintenance alternatives <u>before</u> the design is firm would indeed be an invaluable asset.

2. Clearly there is an order of truth in the postulation that "It takes money to save money." "How much" money is another issue, however. The Department of Defense is spending considerable sums on reaccomplishing the scheduled maintenance programs of existing aircraft systems. At the department level, an overall savings appears almost certain. For some individual systems, however, the cost versus benefit payoff may not be so readily apparent. At issue here are such questions as fleet size and remaining system life to disposal, versus the cost of MSG-2 analysis (contractual expense, in-house salaries, publication changes, training, etc.).

3. OSD guidance calls for eventual RCM application to non-aeronautical equipment. The basic concept of a rationale for maintenance actions that capitalizes upon inherent reliability seems equally applicable in all cases. The precise form of existing MSG-2 logic may not be. Logic tree questions concerning "observable" failures for instance may require some modification in the non-aeronautical arena. Criticality of truck engine versus aircraft engine component failures are, of course, at variance. In short, the basic RCM premise would appear adaptable in the non-aeronautical world. The detailed mechanics of "how" this will be accomplished is not yet fully defined, but should not provide insurmountable difficulties either. The task is workable and should be undertaken expeditiously.

4. A measure of duplication exists in individual Service RCM training programs. With the Air Force exploring the development of an AFIT course and the Army's timing program in its relatively infant stages, the time is ripe for a triservice cooperative effort in this area.

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